SUBCOURSE EN5151

EDITION A

DESIGN FORMS FOR A CONCRETE WALL

"LET US TRY"

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

DESIGN FORMS FOR A CONCRETE WALL

Subcourse EN5151

EDITION A

United States Army Engineer School
Fort Leonard Wood, Missouri 65473

5 Credit Hours

Edition Date: December 1995

SUBCOURSE OVERVIEW

This subcourse addresses the principles of designing wooden wall forms for concrete. One of the carpenter's most important concerns is to ensure that all wooden concrete wall forms are designed for strength and durability. In this subcourse you will be shown how to properly select the materials and spacing of these materials to gain that desired strength. As a carpenter, you must be able to construct these wall forms to support the concrete during placement and initial set period. This will be performed in accordance with Field Manual (FM) 5-742.

There are no prerequisites for this subcourse.

The lessons in this subcourse reflect the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest official publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

TERMINAL LEARNING OBJECTIVE:

ACTION: You will describe procedures used to design and construct wooden forms for concrete walls.

CONDITION: You will be given the material contained in this subcourse and an Army Correspondence Course Program (ACCP) examination response sheet.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70 percent the subcourse examination.

TABLE OF CONTENTS

LESSON

DESIGN FORMS FOR A CONCRETE WALL

Critical Task 051-199-4014

OVERVIEW

<u>LESSON DESCRIPTION:</u>

In this lesson you will learn what materials to select and the procedures necessary in designing a wooden wall form for a concrete wall. The procedures must be performed in a step-by-step process and will be presented in that manner in this lesson.

<u>TERMINAL LEARNING OBJECTIVE:</u>

ACTION	You will deign a wooden form for concrete walls.
CONDITION	You will be given subcourse booklet EN5151 and complete the review exercise.
STANDARD:	You must complete the lesson and the practical exercise.
REFERENCES:	The material contained in this lesson was derived from FMs 5-34, 5-426, and 5-742; and STPs 5-12B4-SM-TG; and 5-51B12-SM-TG.

INTRODUCTION

It is very important that you, as a carpenter, learn the processes involved with the designing of forms for concrete walls. Your first step is to learn the different names of various components of wooden concrete wallforms. This will enable you to determine what type and size of materials to use and where to place these specific members. Your next step is to become an expert in determining the spacing of each of these supporting members. This will enable you to design a concrete form that will successfully handle concrete during the placing and setting up periods.

PART A: MATH REVIEW

Designing concrete forms, like other construction tasks, requires the use of a basic tool. If used skillfully, the “tool”-mathematics-will help you to complete this task.

Before you start the subcourse lesson, you need to perform a short review of the various types of math problems that you will encounter throughout. If you know how to add, subtract, multiply, divide, and are familiar with the operation symbols, you will proceed through this lesson without any difficulty. On the other hand, if you have trouble, be patient. Examples explaining each problem are included in this lesson. Just follow the directions, keeping in mind that you learn best by actually working out the solutions to the problems on paper.

MATH EXERCISE

Space has been provided below each question for you to work out your solution to each problem. After completing the questions, turn to page 1-4 and check your solutions with the review exercise answers and feedback sheet.

1. Convert 93 feet into inches.

2. How many 8-inch stakes can you cut from a piece of lumber that is 2 inches by 4 inches by 16 feet long?

3. How many board feet are in a piece of lumber that is 2 inches by 6 inches by 12 feet long?

4. How many 28-inch-long stakes can you cut from a 7-foot stake that is a piece of a 2 by 4?

5. How many square feet of plywood will you need to build a form for a small retaining wall that is 8 feet long and 24 inches high?

6. How many 3 foot lengths can you cut from three rolls of tie wire that are 500 feet long?

7. How many cubic yards of concrete will it take to fill a concrete form that is 40 feet long 34 inches wide, and 6 inches deep?

8. How many cubic yards of concrete do you need to place concrete in a sidewalk that is 4 feet wide, 35 feet long, and 4 inches thick? Add a 20 percent waste factor.

9. How many cubic yards of concrete do you need to place concrete in a footer that is 18 feet long, 12 inches wide, and 6 inches thick? Add a 10 percent waste factor.

10. How many cubic yards of concrete do you need to fill a column that is 18 inches square and 12 feet high?

REVIEW EXERCISE ANSWER KEY AND FEEDBACK

Item	Correct Answer	
1.	1,116 inches	93 x 12 = 1,116
2.	24 pieces	16 x 12= 192 ÷ 8 = 24
3.	12 board feet	2 x 6 x 2 = 144 ÷ 12 = 12
4	3 stakes	12 x 7 = 84 ÷ 28 = 3
5.	32 square feet	8 x 2 = 16 x 2 (sides) = 32
6.	500	500 x 3 = 1,500 ÷ 3 = 500
7.	2.1 cubic yards	40 x 34 ÷ 12 = 113.3 x 6 ÷ 12 = 56.67 40 x 34 = 1,360 x 0.5 = 680.0 680.0 ÷ 27 = 25.18 56.67 ÷ 27 = 2.1
8.	2.05 cubic yards	35 x 4 = 140 x 0.33 = 46.20 46.20 ÷ 27 = 1.71 1.71 x 0.20 = 0.3420 1.71 + 0.34 =2.05
9.	36 cubic yards	18 x 1 = 18 x 0.5 = 9.0 9.0 ÷ 27 = 0.33 0.33 x 0.10 = 0.0330 0.33 ÷ 0.03 = 0.36
10.	1 cubic yard	18 ÷ 12 x 18 ÷ 12 x 12 = 27 1.5 x 1.5 x 12 = 27 27 ÷ 27 = 1

PART B: SELECT MATERIALS FOR WALL FORMS

Selecting the materials for wallforms is the first step in the process of designing a concrete wall. You will cover the remaining steps in part C of this subcourse.

Step 1. Determine the materials to select for wall forms. To determine the materials to select for wall forms, you will need to understand what materials are available and which to use. Material and sizes to select from are-

Sheathing. Sheathing forms the vertical surfaces of a concrete wall. The materials to be used for sheathing are normally 1- by 4-inch or 1- by 6-inch boards and 5/8- or 3/4-inch plywood.

You should select plywood whenever possible because of its ability to cover large areas with a single sheet The ease of erection, economy, and strength are some of the reasons for selecting plywood. In addition, you may select/use option of 1/2-inch or 1-inch plywood when/if available.

Sheathing can be 1 1/4, 1 1/2-, or 2-inch-thick boards of any width; however, these sizes are used only on extra-large forms such as seawalls and dams. <u>The type of sheathing selected will depend upon the type available at the supply point, or on the materials available list</u>.

Studs. Studs add vertical rigidity to the wall forms. Studs are made of 2- by 4-inch material; however, they are available in sizes of 4 by 4 or 2 by 6. For economy, use 2 by 4s if possible.

NOTE: The larger the material, the greater the stud load.

Wales. Wales reinforce the studs when they extend upward more than 4 or 5 feet. Wales are structured of the same materials as studs. Usually 2 by 4s are used because they are economical. However, wales may also be made of 4 by 4 or 2 by 6s. Wales are <u>always</u> nailed together to make them doubled, thereby increasing their strength. The <u>exception</u> to wales being nailed together is when you are substituting heavier material; such as a single 4 by 4 for two 2 by 4s.

Bracing. Braces help stabilize the form. To prevent movement and maintain alignment, the form is normally braced with 2- by 4-inch material. Bracing may be made of 4 by 4s or 2 by 6s. The choice would depend upon the size of the form and the type of material available.

Tie wires. Tie wires secure the formwork against the lateral pressure of the plastic concrete. They always have double strands. Tie wires are normally made of No. 8 or 9 gauge annealed (soft) wire, but larger wire or barbed wire may also be used. The <u>larger</u> the wire <u>number</u>, the <u>smaller</u> the <u>size</u> of the wire. Since barbed wire is doubled, you can use a smaller size wire.

Work the following problems to see how well you understand the concepts covered in step 1. See page 1-31 for the solution to each problem.

Following each question is a list of materials to use for the function indicated. Select the best materials for that function.

PROBLEM 1

The best materials for <u>sheathing</u> on a wall form are-

A. 3/4-inch plywood and 1- by 6-inch material

B. 2- by 4- and 2- by 10-inch material

C. 3- by 6- and 2- by 6-inch material

D. 1- by 2- and 1- by 1-inch material

PROBLEM 2

The best materials for <u>studs</u> are-

A. 1- by 4- and 1- by 6-inch material

B. 2- by 2-inch material and 3/4-inch plywood

C. 2- by 6- and 2- by 4-inch material

D. 1- by 2- and 2- by 10-inch material

PROBLEM 3

The best materials for <u>wales</u> are-

A. 1- by 6- and 1- by l0-inch material

B. 2- by 10-inch material and 1/2-inch plywood

C. 3- by 6- and 2- by 2-inch material

D. 2- by 4- and 4 by 4-inch material

PROBLEM 4

The best materials for the bracing on a wall form are-

A. 1- by 4- and 1- by 6-inch material

B. 2- by 10- and 1- by 2-inch material

C. 1- by 4- and 4- by 4-inch material

D. 4- by 4- and 2- by 4-inch material

PROBLEM 5

The best materials for tie wire on a wall form are:

A. 1/8-inch wire rope and No. 10 annealed wire

B. No. 10-barbed wire and No. 10 annealed wire

C. No. 8 and No. 9 annealed wire

D. No. 8 barbed wire and No. 4 hard-drawn wire

PART C: COMPLETE DESIGN PROCEDURE

You completed step 1 of this process when you determined the materials needed to construct a concrete form in part B. Now you are ready to begin the actual design of the form by completing steps 2 through 17.

You will continue this process by first determining the rate of placing or vertical fill rate per hour of the form. This computation involves three parts. You will determine the mixer output (step 2), the plan area (step 3), and the rate of placing (step 4). Each of these steps will be explained in the following pages.

Step 2. Determine the mixer output. You determine the mixer output by dividing the mixer capacity by the batch time. The unit measurement for mixer output is measured in cubic feet per hour. If you use more than one mixer, multiply output by the number of mixers. Batch time includes loading all ingredients, mixing, and unloading. Batch time is measured in minutes. To determine the mixer output use this formula:

$$\text{Mixer output (cu ft/hr)} = \frac{\text{mixer capacity (cu ft)}}{\text{batching time (min)}} \times \frac{60\ \text{(min)}}{1\ (hr)} \times \text{number of mixers}$$

where-
cu ft = cubic feet cu/hr = cubic feet per hour, and min = minute

NOTE: If the answer contains a decimal, round up to the next whole number.

EXAMPLE:

Determine the mixer output, if the mixer's capacity is 16 cubic feet, the batching time is 7 minutes, and the mixer operates for 1 hour.

$$\text{Mixer output} = \left(\frac{16}{7} \times \frac{60}{1} \times 1\right) = \frac{960}{7} = 137.14,\ \text{use } 138\ \text{cu ft/hr}$$

Step 3. Determine the plan area. The plan area is the area enclosed by the form. You determine the plan area by multiplying the length by width. It is measured in square feet. To determine the plan area, use this formula:

Plan area (sq ft) = form L (ft) x W (ft)

where-
ft = feet, L = length, sq ft = square feet, and W = width

EXAMPLE:

Determine the plan area for a concrete wall form that is 15 feet long by 2 feet wide by 6 feet high.

Plan area = 15 x 2= 30 sq ft

Step 4. Determine the rate of placing. Having determined the mixer output (step 2) and the plan area (step 3), it is now time to compute the rate of placing. You determine the rate of placing of concrete in the form by dividing the mixer output by the plan area. Rate of placing is measured in vertical feet per hour. To determine the rate of placing, use this formula and the following procedures:

$$R\ (ft/hr) = \frac{mixer\ output\ (cu\ ft/hr)}{plan\ area\ (sq\ ft)}$$

where-
ft/hr = feet per hour and R = rate of placing

- If the answer contains a decimal, round off to one decimal place. For example, for 1.41, use 1.4; for 1.57, use 1.6.

- The rates of placing should be kept below 5 feet/hour for economical design. Rate of placing <5 feet/hour.

EXAMPLE:

Determine the rate of placing if the mixer output is 7 cubic yards per hour (189 cubic feet/hour) and the plan area is 15 feet by 2 feet.

$$R = \left(\frac{189}{15 \times 2}\right) = \frac{189}{30} = 6.3.\ \ Use\ 5\ ft/hr$$

Work the following problems to see how well you understand the concepts you just covered in steps 2, 3, and 4. See page 1-31 for the solution to each problem.

PROBLEM 6

Determine the plan area for a form that is 33 feet long by 7.5 feet high by 3 feet wide.

A. 30

B. 33

C. 66

D. 99

PROBLEM 7

Determine the total mixer output if the mixer capacity is 16 cubic feet and the batching time is 6 minutes with two mixers operating for 1 hour.

A. 290

B. 308

C. 320

D. 328

PROBLEM 8

Determine the rate of placing if the mixer output is 7 cubic yard per hour (189 cubic feet per hour) and the plan area is 33 feet by 3 feet.

A. 0.8

B. 1.9

C. 2.3

D. 3.1

Step 5. Determine the concrete placing temperature. You determine the concrete placing temperature by making a reasonable estimate of the placing temperature of the concrete. During the seasons, you will be considering the ambient (environmental) temperature. The optimum concrete temperatures are 55 degrees (°) to 73° Fahrenheit (F). If the temperature is too cold, heated aggregate and warm water are used to bring the concrete temperature up to an acceptable level. If the temperature is too hot, ice water may have to be used. The air temperature is normally 10° F above the concrete temperature. You will be performing this step as you proceed through step 6.

Step 6. Determine the maximum concrete pressure. You determine the maximum concrete pressure by using Figure 1-1, page 1-12. Be as accurate as possible when using the graph. The use of a straight edge is highly recommended. You must estimate the concrete temperature, (step 5) first. To determine the maximum concrete pressure, use Figure 1-1, and the following procedures:

- Enter the bottom of the graph at the position where your rate of placing rate is located.
- Move vertically until you intersect the correct temperature curve. Estimate as closely to the temperature range as possible.
- Move to the far left side of the graph and estimate as closely as possible to the correct pressure number. This number is the *maximum concrete pressure.* It reads *100 pounds per square feet.*

EXAMPLE:

Determine the maximum concrete pressure if the rate of placing is 2.5 feet/hour and the concrete temperature is 60° F.

500 pounds per square feet

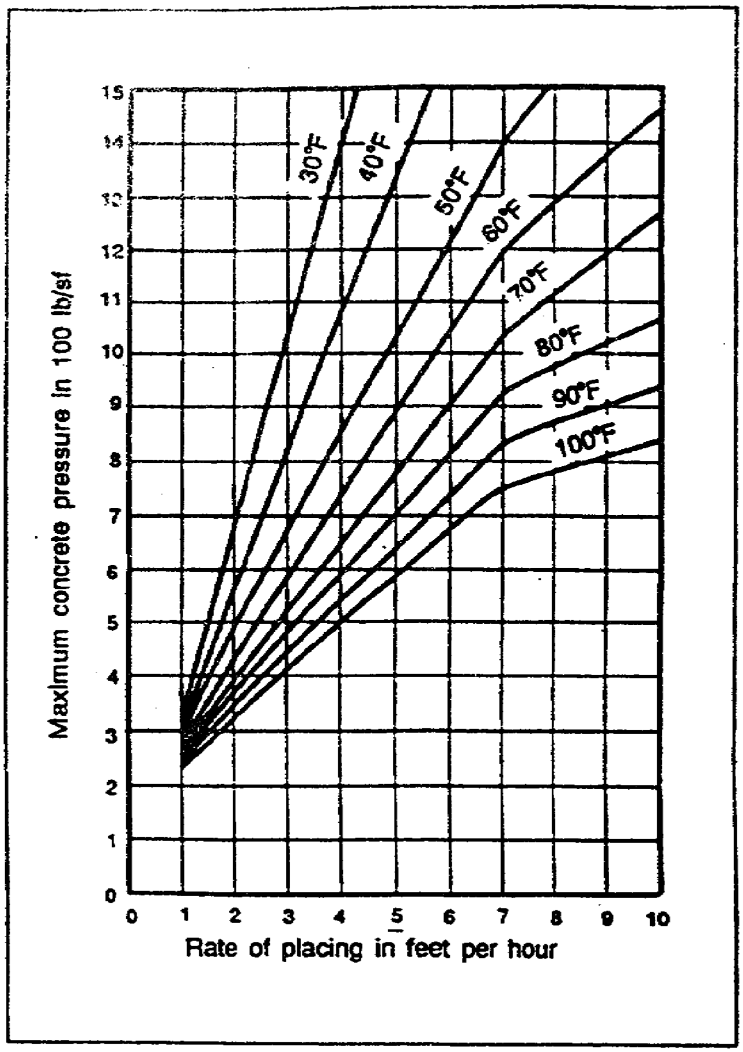

Figure 1-1. Maximum concrete pressure graph

For more accurate determination of maximum concrete pressure, use the following formula:

NOTE: This formula will be used in place of Figure 1-1 when determining maximum concrete pressure throughout the subcourse and in the examination.

$$\text{Maximum concrete pressure} = \frac{150 + (9{,}000 \times R)}{\text{Temperature}}$$

EXAMPLE:

Determine the maximum concrete pressure if the rate of placing is 2.5 feet/hour and the concrete temperature is 60° F.

525 pounds per square feet

Maximum concrete pressure =

$$(150 + \frac{9{,}000 \times (2.5)}{60}) = \frac{22{,}500}{60} = 375 + 150 = 525 \ psf$$

where-
psf = pounds per square feet

Work the following problems to see how well you understand the concept you just reviewed in steps 5 and 6. See page 1-31 for the solution to each problem.

PROBLEM 9

Determine the maximum concrete pressure if the rate of placing is 1.6 feet per hour and the concrete temperature is 70° F.

A. 205

B. 256

C. 300

D. 356

PROBLEM 10

Determine the maximum concrete pressure if the rate of placing is 19 feet per hour and the concrete temperature is 50° F.

A. 400

B. 492

C. 500

D. 518

Step 7. Determine the maximum stud spacing. Determining the maximum stud spacing depends on the type of sheathing used-boards or plywood. Maximum stud spacing is found by using either Table 1-1 for board sheathing or Table 1-2 for plywood sheathing. Be sure to use the correct one.

Table 1-1. Maximum stud or joist spacing for support of board sheathing

Maximum Concrete Pressure (psf)	Normal Thickness of S4S Boards (in)			
	1	1¼	1½	2
75	30	37	44	50
100	28	34	41	47
125	26	33	39	44
150	25	31	37	42
175	24	30	35	41
200	23	29	34	39
300	21	26	31	35
400	18	24	29	33
500	16	22	27	31
600	15	20	25	30
700	14	18	23	28
800	13	17	22	26
900	12	16	20	24
1,000	12	15	19	23
1,100	11	15	18	22
1,200	11	14	18	21
1,400	10	13	16	20
1,600	9	12	15	18
1,800	9	12	14	17
2,000	8	11	14	16
2,200	8	10	13	16
2,400	7	10	12	15
2,600	7	10	12	14
2,800	7	9	12	14
3,000	7	9	11	13

To find the maximum stud spacing, use Table 1-1 or 1-2 and the following procedures:

- Find the Maximum concrete pressure in the left column. If the value is not listed, round the load up to the next value on the table. For example, for 340 pounds per square feet, use 400 pounds per square feet

- Move across the row to the column headed by the sheathing thickness being used. The intersecting number is the *maximum stud spacing* and is in *inches*.

Table 1-2. Maximum stud or joist spacing for support of plywood sheathing

Maximum Concrete Pressure (psf)	Strong Way (5-ply sanded, face grain perpendicular to the stud)				Weak Way (5-ply sanded, face grain parallel to stud)			
	1/2 in	5/8 in	3/4 in	1 in (7 ply)	1/2 in	5/8 in	3/4 in	1 in (7 ply)
75	20	24	26	31	13	18	23	30
100	18	22	24	29	12	17	22	28
125	17	20	23	28	11	15	20	27
150	16	19	22	27	11	15	19	25
175	15	18	21	26	10	14	18	24
200	15	17	20	25	10	13	17	24
300	13	15	17	22	8	12	15	21
400	12	14	16	20	8	11	14	19
500	11	13	15	19	7	10	13	18
600	10	12	14	17	6	9	12	17
700	10	11	13	16	6	9	11	16
800	9	10	12	15	5	8	11	15
900	9	10	11	14	4	8	9	15
1,000	8	9	10	13	4	7	9	14
1,100	7	9	10	12	4	6	8	12
1,200	7	8	10	11		6	7	11
1,300	6	8	9	11		5	7	11
1,400	6	7	9	10		5	6	10
1,500	5	7	9	9		5	6	9
1,600	5	6	8	9		4	5	9
1,700	5	6	8	8		4	5	8
1,800	4	6	8	8		4	5	8
1,900	4	5	8	7		4	4	7
2,000	4	5	7	7			4	7
2,200	4	5	6	6			4	6
2,400		4	5	6			4	6
2,600		4	5	5				5
2,800		4	4	5				5
3,000			4	5				5

NOTE: All plywood sheathing problems and practice exercises will be using the Strong Way column in Table 1-2.

EXAMPLE:

Determine the maximum stud spacing, in inches, if the maximum concrete pressure is 320 pounds per square feet and a sheathing thickness of 1-inch-boards is used.

18 inches

Work the following problem to see how well you understand the concept you just reviewed in step 7. See page 1-31 for the solution in this problem.

PROBLEM 11

Determine the maximum stud spacing, in inches, if the maximum concrete pressure is 700 pounds per square feet and sheathing thickness of 1-inch boards is used.

A. 14

B. 15

C. 16

D. 21

Step 8. Determine the uniform load on a stud. You determine the uniform load on a stud by multiplying the maximum concrete pressure (step 6) by the stud spacing (step 7). Uniform load on a stud is measured in pounds per linear feet. To determine uniform load on a stud, use this formula and the following procedures:

$$ULS\ (lb/lin\ ft) = \frac{\text{maximum concrete pressure } (lb/sq\ ft) \times \text{maximum stud spacing } (in)}{12\ (in/ft)}$$

where to-
in = inch, lb/lin ft = pounds per linear feet, lb/sq ft = pounds per square feet and ULS = uniform load on a stud

- Use the actual concrete pressure, not the rounded up figure that was used to obtain the stud spacing in step 7.

- Carry out the answer two decimal places.

EXAMPLE:

Determine the uniform load on a stud if the maximum concrete pressure is 410 pounds per square feet and the maximum stud spacing is 18 inches.

$$ULS = \left(\frac{410 \times 18}{12}\right) = \frac{7{,}380}{12} = 615\ lb/lin\ ft$$

Work the following problem to see how well you understand the concept you just reviewed in step 8. See page 1-31 for the solution to this problem.

PROBLEM-12

Determine the uniform load on a stud if maximum concrete pressure is 350 pounds per square feet and the maximum stud spacing is 20 inches.

A. 350.38
B. 560.70
C. 583.33
D. 593.35

STEP 9. Determine the maximum wale spacing. Determine the maximum wale spacing by using Table 1-3 the following procedures:

- Find the uniform load in the left-hand column. If the value you have for this load is not listed in the table, round up to the nearest value given. For example, for 840 pounds per linear feet, use 900 pounds per linear feet.

- Move across this row to the column headed by the correct size of the stud being used. The intersecting number is the *maximum wale spacing* and is given in *inches*.

Table 1-3. Maximum wale spacing.

Uniform Load (lb/lin ft)	2 x 4	2 x 6	3 x 6	4 x 4	4 x 6
100	60	95	120	92	131
125	54	85	110	82	124
150	49	77	100	75	118
175	45	72	93	70	110
200	42	67	87	65	102
225	40	63	82	61	97
250	38	60	77	58	92
275	36	57	74	55	87
300	35	55	71	53	84
350	32	50	65	49	77
400	30	47	61	46	72
450	28	44	58	43	68
500	27	41	55	41	65
600	24	38	50	37	59
700	22	36	46	35	55
800	21	33	43	32	51
900	20	31	41	30	48
1,000	19	30	38	29	46
1,200	17	27	35	27	42
1,400	16	25	33	25	39
1,600	15	23	31	23	36
1,800	14	22	29	22	34
2,000	13	21	27	21	32
2,200	13	20	26	20	31
2,400	12	19	25	19	30
2,600	12	19	24	18	28
2,800	11	18	23	17	27
3,000	11	17	22	17	26
3,400	10	16	21	16	25
3,800	10	15	20	15	23
4,500	9	14	18	13	21

EXAMPLE:

Find the maximum wale spacing if the uniform load is 1,560 pounds per linear feet and the studs are 2 by 6 inches.

23 inches

Work the following problem to see how well you understand the concept you just reviewed in step 9. See page 1-31 for the solution to this problem.

PROBLEM 13

Find the maximum wale spacing if the uniform load is 581 pounds per linear feet and the studs are 2 by 4 inches.

A. 19
B. 22
C. 24
D. 27

Step 10. Determine the uniform load on a wale. You determine the uniform load on a wale by multiplying the maximum concrete pressure (step 6) by the maximum wale spacing (step 9). Uniform load on a wale is measured in pounds per linear foot. To determine the uniform load on a wale, use this formula and the following procedures:

$$\text{ULW (lb/lin ft)} = \frac{\text{maximum concrete pressure (psf)} \times \text{maximum wale spacing (in)}}{12 \text{ (in/ft)}}$$

where-
ULW = uniform load on a wale

- Use the actual concrete pressure, not the rounded off figure that you used to obtain the wale spacing (step 9).

- Carry out your answer two decimal places.

EXAMPLE:

Determine the uniform load on a wale if the maximum concrete pressure is 550 pounds per square feet and the maximum wale spacing is 20 inches.

$$ULW = \left(\frac{550 \times 20}{12}\right) = \frac{11{,}000}{12} = 916.67 \; lb/lin\ ft$$

Work the following problem to see how well you understand the concept you just reviewed in step 10. See page 1-31 for the solution to this problem.

PROBLEM 14

Determine the uniform load on a wale if the maximum concrete pressure is 350 pounds per square feet and the maximum wale spacing is 26 inches.

A. 350.83

B. 758.33

C. 780.53

D. 810.66

To determine the tie wire spacing, you will need to perform the steps sequentially. First, compute tie wire spacing based on wale size (step 11). Next, you will need to compute the tie wire spacing based on tie wire strength (step 12). Last, compare the two to select the maximum allowable tie wire spacing (step 13). The following pages will cover each of these steps.

Step 11. Determine tie wire spacing based on wale size. <u>Tie wire spacing based on wale size</u> is found by using Table 1-4. The sizes at the top of the table refer to the wale material being used. The table is divided into two halves, single-wale members located on the left, and double-wale members on the right.

Table 1-4. Maximum spacing of supporting members (wales, ties, stringers, and 4- by 4-inch and larger shores)

Uniform Load (lb/in ft)	Supported member size (S4S)									
	Single members					Double members				
	2 x 4	2 x 6	3 x 6	4 x 4	4 x 6	2 x 4	2 x 6	3 x 6	4 x 4	4 x 6
100	60	95	120	92	131	85	126	143	111	156
125	54	85	110	82	124	76	119	135	105	147
150	49	77	100	75	118	70	110	129	100	141
175	45	72	93	70	110	64	102	124	96	135
200	42	67	87	65	102	60	95	120	92	131
225	40	63	82	61	97	57	89	116	87	127
250	38	60	77	58	92	54	85	109	82	124
275	36	57	74	55	87	51	81	104	78	121
300	35	55	71	53	84	49	77	100	75	118
350	32	50	65	49	77	46	72	93	70	110
400	30	47	61	46	72	43	67	87	65	102
450	28	44	58	43	68	40	63	82	61	97
500	27	41	55	41	65	38	60	77	58	92
600	24	38	50	37	59	35	55	71	53	84
700	22	36	46	35	55	32	51	65	49	77
800	21	33	43	32	51	30	47	61	46	72
900	20	31	41	30	48	28	44	58	43	68
1,000	19	30	38	29	46	27	43	55	41	65
1,200	17	27	35	27	42	25	39	50	38	59
1,400	16	25	33	25	39	23	36	46	35	55
1,600	15	23	31	23	36	21	34	43	33	51
1,800	14	22	29	22	34	20	32	41	31	48
2,000	13	21	27	21	32	19	30	39	29	46
2,200	13	20	26	20	31	18	29	37	28	44
2,400	12	19	25	19	30	17	27	36	27	42
2,600	12	19	24	18	28	17	26	34	26	40
2,800	11	18	23	17	27	16	25	33	25	39
3,000	11	17	22	17	26	15	24	32	24	38
3,400	10	16	21	16	25	14	23	30	22	35
3,800	10	15	20	15	23	14	21	28	21	33
4,500	9	14	18	13	21	12	20	25	19	30

To find the tie-wire spacing, use Table 1-4, page 1-21 and the following procedures:

- Find the uniform load on a wale in the left-hand column of the table. If the value you have for this load is not listed in the table, round up to the nearest value given. For example, for 1,250 pounds per linear feet, use 1,400 ponds per linear feet.

- Move across this row to either the single- or double-wale members section. Then locate the wale size that you will be using. The intersecting number is the *tie-wire spacing*, in *inches*, based on wale size.

EXAMPLE:

Determine the tie-wire spacing in inches, if the uniform load on a wale is 125 pounds per linear feet and 4- by 4-single wales are used.

82 inches

Work the following problem to see how well you understand the concept you just reviewed in step 11. See page 1-31 for the solution to this problem.

PROBLEM 15

Determine the tie wire spacing, in inches, if the uniform load is 756 pounds per linear feet and 2- by 4-double wales are used.

A. 30

B. 43

C. 46

D. 72

Step 12: Determine wire spacing based on tie-wire strength. You determine wire spacing based on tie-wire strength by dividing the tie breaking strength (step 12) by the uniform load on a wale (step 10). To determine wire spacing based on tie-wire strength, use this formula and the following procedures:

$$\text{Tie-wire spacing (in)} = \frac{\text{tie-wire strength (lb)} \times 12 \text{ (in)}}{\text{ULW (lb/lin ft)}}$$

where-
ULW = uniform load on a wale

- If you do not know the strength of the tie wire, the minimum breaking load for a double strand of wire is given in Table 1-5.
- If the tie-wire spacing is not a whole number of inches, round the value down to the next lower whole number of inches. For example, for 11.4, use 11; for 12.7, use 12.

Table 1-5. Average breaking load of tie material (lb).

Steel Wire	
Size of wire gauge number	**Minimum breaking load, double strand (lb)**
8	1,700
9	1,420
10	1,170
11	930
Barbed Wire	
Size of wire gauge number	**Minimum breaking load (lb)**
12 1/2	950
13*	660
13 1/2	950
14	650
15 1/2	850
Tie Rod	
Description	**Minimum breaking load (lb)**
Snap ties	3,000
Pencil rods	3,000
* Single-strand barbed wire.	

EXAMPLE:

Determine the tie-wire spacing, in inches, if the uniform load on a wale is 1,250 pounds per linear feet and you are using a No. 9-gauge steel tie-wire.

$$\text{Tie wire spacing} = \frac{(1{,}420 \times 12)}{1{,}250} = \frac{17{,}040}{1{,}250} = 13.6 \quad \textit{Use 13 inches}$$

Work the following problem to see how well you understand the concept you just reviewed in step 12. See page 1-31 for the solution to this problem.

PROBLEM 16

Determine the tie-wire spacing, in inches, if the uniform load on the wale is 1,200 pounds per linear feet and and you will using a No. 8-gauge steel tie-wire.

A. 14

B. 16

C. 17

D. 18

Step 13. Determine the maximum tie-wire spacing. You determine the maximum tie-wire spacing by comparing the results from steps 11 and 12, then use the smaller of the two tie-wire spacings as the maximum tie wire spacing.

EXAMPLE:

Determine the maximum tie-wire spacing value by comparing the following measurement:

- Tie-wire spacing based on wale size = 24 inches
- Tie-wire spacing based on wire strength = 20 inches

Use the smaller tie wire spacing (20 inches).

PROBLEM 17

Work the following problem to see how well you understand the concept you just reviewed in step 13. See page 1-32 for the solution to this problem.

Determine the maximum tie-wire spacing value by comparing the following measurement:

- 16 inches (based on wire strength)
- 26 inches (based on wale size)

STEP 14. Determine the location of the ties. Now that you have obtained the maximum stud spacing (step 7) and the maximum tie wire spacing (step 13), it is time to compare the two. The correct location (spacing) of your ties must be determined to ensure that the form design has the proper strength.

NOTE: This step is performed only when using wires. If you use snap ties, the spacing was found in step 13.

Determining the location of the ties requires consideration of two factors when comparing stud spacing and tie wire spacing:

- If the maximum tie spacing is less than the maximum stud spacing, reduce the maximum stud spacing to equal the maximum tie-wire spacing and install the tie at the intersections of the studs and wales or get a stronger wire.

- If the maximum tie spacing is greater than or equal to the maximum stud spacing, use the size for the maximum stud spacing and install the tie at the intersections of the studs and wales.

EXAMPLE:

Determine where the ties will be made if the maximum stud spacing is 28 inches and the maximum tie wire spacing is 24 inches.

- 28 inches (expand stud spacing)

- 24 inches (reduce stud spacing)

Reduce the stud spacing to 24 inches and install the tie at the intersections of the studs and wales.

Work the following problem to see how well you understand the concept you just reviewed in step 14. See page 1-32 for the solution to this problem.

PROBLEM 18

Determine where the ties will be made if the maximum stud spacing is 14 inches and the maximum tie wire spacing is 20 inches.

- 14 inches (reduce stud spacing)

- 20 inches (expand stud spacing)

Step 15. Determine the number of studs for one side. You determine the number of studs for one side of a form by dividing the form length by the maximum stud spacing (step 7 or step 14 if stud spacing has been reduced). Add one to this number, and round up to the next value if your answer contains decimal. Your first and last studs must be placed at the ends of the form, even though the spacing between the last two studs may be less than the maximum allowable spacing. To determine the number of studs for one side of the form, use this formula and the following procedures:

$$\text{Number of studs} = \frac{\text{length of form (ft)} \times 12 \text{ (in)}}{\text{maximum stud spacing (in)}} + 1$$

- If your answer contains a decimal, round up to the next whole number.
- The spacing between the last two studs may be less than the maximum allowable spacing.

EXAMPLE:

Determine how many studs are required for one side of the form if the stud spacing is 24 inches and the form length is 28 feet.

$$\text{Number of studs} = (\frac{28 \times 12\ )}{24} + 1 = \frac{336}{24} + 1 = 14 + 1 = 15 \text{ studs}$$

Work the following problem to see how well you understand the concept you just reviewed, in step 15. See page 1-32 for the solution to this problem.

PROBLEM 19

Determine how many studs are required for one side of the form if the stud spacing is 14 inches and the form length is 24 feet.

A. 19

B. 20

C. 21

D. 22

Step 16. Determine the number of double wales for one side. You determine the number of double wales for one side of a form by dividing the form height by the maximum wale spacing (step 9). Wall studs over 4 feet require double walls. To determine the number of double wales for one side, use this formula and the following procedures:

$$\text{Number of double wales} = \frac{\text{form height (ft)} \times 12 \text{ (in)}}{\text{maximum wale spacing (in)}}$$

- If the answer that you get is not a whole number, round up to the next whole number. For example, for 11.4, use 12; for 12.7, use 13.

- You must place the first wale one-half the maximum wale spacing up from the bottom. The remaining wales are placed at the maximum wale spacings that you previously determined (see Figure 1-2).

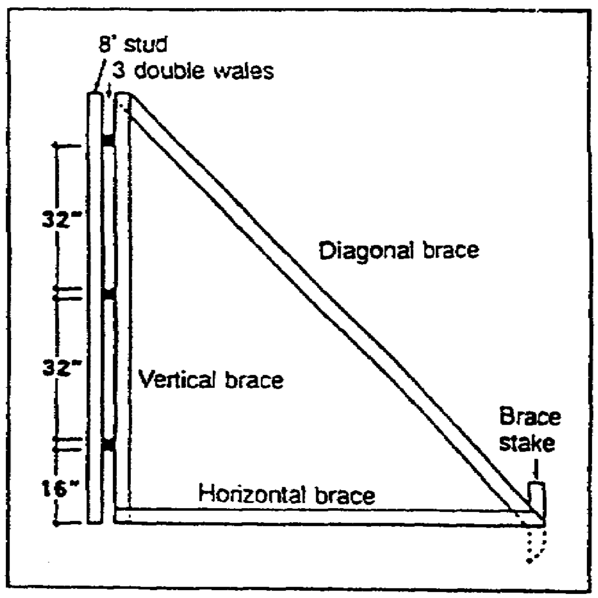

Figure 1-2. Double wales on a 8-foot wall form

EXAMPLE:

Determine how many wales are required for one side of the form if the wale spacing is 32 inches and a form height of 8 feet is used.

$$\text{Number of double wales} = \left(\frac{8 \times 12}{32}\right) = \frac{96}{32} = 3 \text{ wales per side}$$

Work the following problems to see how well you understand the concept you just reviewed in step 16. See page 1-32 for the solution to this problem.

PROBLEM 20

Determine how many wales are required for one side of the form if the wale spacing is 30 inches and the form height is 8 feet.

A. 1

B. 2

C. 3

D. 4

Step 17: Determine the time required to place the concrete. You determine the time required to place the concrete by dividing the height of the form by the rate of placing (step 4). To determine the time required to place the concrete, use the following formula:

$$Time\ to\ place\ concrete\ (hr) = \frac{form\ height\ (ft)}{R\ (in/ft)}$$

NOTE: Round all answers up to the next hour. For example, for 3.6, use 4 hours; for 5.8, use 6 hours; for 2.1, use 3 hours.

EXAMPLE:

Determine how long it will take to place concrete if a form, height is 20 feet and the rate of placing is 1.2 feet per hour.

$$Time\ to\ place\ concrete = \left(\frac{20}{1.2}\right) = 16.66 \quad Use\ 17\ hours$$

Work the following problem to determine how well you understand the concept you just reviewed in step 17. See page 1-32 for the solution to this problem.

PROBLEM 21

Determine, in hours, how long it will take to place concrete if the form height is 12 feet and the rate of placing is 1.6 feet per hour.

A. 6.3

B. 7.5

C. 8.0

D. 8.4

PROBLEMS ANSWER KEY AND FEEDBACK

Problem	Correct Answer
1.	A. 3/4-inch plywood and 1- by 6-inch material (page 1-5)
2.	C. 2- by 6-inch and 2- by 4-inch material (page 1-5)
3.	D. 2- by 4-inch and 4- by 4-inch material (page 1-5)
4.	D. 4- by 4-inch and 2- by 4-inch material (page 1-5)
5.	C. No. 8 and No. 9 annealed wire (page 1-5)
6.	D. 99. Plan area = 33 x 3 = 99 square feet (page 1-8)
7.	**C. 320. Mixer output =** $\frac{16}{6} \times \frac{60}{1} \times 2 = \frac{960}{6} = 160 \times 2 = 320$ **cu ft/hr (page 1-8)**
8.	**B. 1.9.** $R = \left(\frac{189}{33 \times 3} = \frac{189}{89}\right) = 1.9$ **ft/hr (page 1-9)**
9.	**D. 356 psf.** $\left(150 + \frac{9{,}000(R)}{\text{temperature}}\right) = 150 + \frac{9{,}000(1.6)}{70} = 355.7.$ **Use 356 psf.(page 1-12)**
10.	**B. 492 psf.** $\left(150 + \frac{9{,}000(R)}{T}\right) = 150 + \frac{9{,}000(1.9)}{50} = 492$ **psf (page 1-12)**
11.	A. 14 inches (page 1-14)
12.	**C. 583.33** **ULS** $= \frac{350 \times 20}{12} = \frac{7{,}000}{12} = 583.33$ **lbs/lin ft (page 1-17)**
13.	C. 24 inches (page 1-18)
14.	**B. 758.33** **ULW** $= \frac{350 \times 26}{12} = \frac{9{,}100}{12} = 758.33$ **lb/lin ft (page 1-20)**
15.	A. 30 inches (page 1-21)
16.	**B. 16** **Tie-wire spacing** $= \frac{1{,}700 \times 12}{1{,}200} = \frac{20{,}400}{1{,}200} = 17.$ **Use 16 inches. (page 1-23)**

Problem	Correct Answer
17.	16 inches. Use the smallest tie-wire spacing. (page 1-25)
18.	Reduce tie stud spacing to 14 inches. (page 1-26)
19.	**D. 22** $= \frac{24 \times 12}{14} + 1 = \frac{288}{14} + 1 = 20.57 + 1 = 21.57$. **Use 22 studs (page 1-27)**
20.	**D. 4. Number of double wales =** $\frac{8 \times 12}{30} = \frac{96}{30} = 3.2$. **Use 4 wales per side. (page 1-28)**
21.	**C. 8.0 Time to place concrete =** $\frac{12}{1.6} = 7.5$. **Use 8.0 hours. (page 1-30)**

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the key that follows. If you answer any item incorrectly, study again that part which contain the portion involved.

There are two problems for this exercise. You will be performing them step by step as you did during the lesson. Step 1, materials to be selected, has been completed for you and appears in each of the problem statements.

Problem 1. You will be designing a form work for a concrete wall that is to be 5 feet high, 140 feet long, and 18 inches thick. You will have three 16-S mixers with a 16 cubic foot capacity to use for concrete mixing. Each has a batch cycle of 3 minutes. The concrete temperature expected to be 80° F. Materials available are: 1-by 12-inch-boards, 2-by 4-inch studs, 2-by 4-inch doubled wales, and 3,000-pound snap ties.

1. Determine, in cubic feet per hour, the total mixer output if the mixer capacity is 16 cubic feet, batching time is 3 minutes, and the 3 mixers will be operating for 1 hour.

   A. 960

   B. 840

   C. 3,200

   D. 7,400

2. Determine the plan area for a concrete wall form that is 140 feet long, 5 feet high and 18 inches thick.

   A. 140

   B. 180

   C. 210

   D. 250

3. Determine the rate of placing, in feet per hour.

   A. 3.8

   B. 4.6

   C. 5.0

   D. 5.6

4. Determine the concrete temperature.

   A. 60

   B. 70

   C. 80

   D. 90

5. Determine the maximum concrete pressure, in pounds per square feet.

   A. 600.3

   B. 630.6

   C. 667.5

   D. 750.5

6. Determine the maximum stud spacing, in pounds per square feet.

   A. 13

   B. 14

   C. 15

   D. 16

7. Determine the uniform load on a stud, in pounds per linear feet.

   A. 678.3

   B. 738.5

   C. 778.7

   D. 828.5

8. Determine the maximum wale spacing, in inches.

   A. 20

   B. 21

   C. 22

   D. 24

9. Determine the uniform load on a wale, in pounds per linear feet.

   A. 1,168.13

   B. 1,268.25

   C. 1,325.35

   D. 1,362.73

10. Determine the tie-wire spacing, based on wale size.

   A. 21

   B. 23

   C. 25

   D. 35

11. Determine the tie-wire spacing, based on tie wire strength.

    A. 26

    B. 28

    C. 32

    D. 30

12. Determine the maximum tie-wire spacing, in inches.

    A. 21

    B. 25

    C. 23

    D. 26

13. Determine the adjusted tie-wire/stud spacing.

    A. 18

    B. 20

    C. 25

    D. Does not apply for snap ties

14. Determine how many studs are required for one side of the form.

    A. 121

    B. 122

    C. 126

    D. 131

15. Determine how many double wales will be required for one side.

    A. 2

    B. 3

    C. 4

    D. 5

16. Determine the time required to place the concrete, in hours.

    A. 0.5

    B. 1.0

    C. 1.5

    D. 2.0

Problem 2. You will be designing a form work for a concrete wall that is to be 6.5 feet high, 92 feet long, and 12 inches thick. You will have one M919 mobile mixer with 27-cubic-foot capacity to use for concrete mixing. It has a 1-cubic-yard batch cycle for every four minutes. The concrete temperature is expected to be 50° F. Materials available are: 5/8-inch-plywood sheathing, 2- by 4-inch lumber for studs, 4- by 4-inch lumber for wales, and No. 9 wire for ties.

17. Determine the total mixer output in cubic feet per hour, if the mixer capacity is 27 cubic feet (1 cubic yard) with batching time of four minutes and you have one mixer operating for an hour.

A. 310

B. 405

C. 435

D. 450

18. Determine the plan area, in square feet, for a concrete wall form that is 92 feet long, 6.5 feet high, and 12 inches thick.

A. 46

B. 92

C. 112

D. 598

19. Determine the rate of placing, in feet per hour.

A. 3.8

B. 4.4

C. 4.6

D. 5.6

20. Determine the concrete temperature.

A. 50

B. 60

C. 70

D. 80

21. Determine the maximum concrete pressure, in pounds per square feet.

A. 667

B. 750

C. 842

D. 942

22. Determine the maximum stud spacing, in pounds per square feet.

    A. 6

    B. 7

    C. 8

    D. 9

23. Determine the uniform load on a stud, in pounds per linear feet.

    A. 678.5

    B. 706.5

    C. 738.5

    D. 828.5

24. Determine the maximum wale spacing, in inches.

    A. 20

    B. 21

    C. 22

    D. 24

25. Determine the uniform load on the wale, pounds per linear feet.

   A. 1,325.5

   B. 1,468.5

   C. 1,568.5

   D. 1,648.5

26. Determine the tie-wire spacing, based on wale size.

   A. 21

   B. 22

   C. 23

   D. 25

27. Determine the tie-wire spacing, based on tie-wire strength.

   A. 8

   B. 10

   C. 12

   D. 14

28. Determine the maximum tie-wire spacing, in inches.

A. 8

B. 9

C. 10

D. 11

29. Determine the adjusted tie-wire/stud spacing, in inches.

A. 6

B. 8

C. 9

D. 10

30. Determine how many studs are required for one side of the form.

A. 120

B. 121

C. 124

D. 126

31. Determine how many double wales will be required for one side.

A. 2

B. 3

C. 4

D. 5

32. Determine the time required to place the concrete, in hours.

A. 0.5

B. 1.0

C. 1.5

D. 2.0

PRACTICE EXERCISE
ANSWER KEY AND FEEDBACK

Problem 1

Item	Correct Answer	
1.	A.	960 (page 1-8)
2.	C.	210 (pages 1-8, and 9)
3.	B.	4.6 (page 1-9)
4.	C.	80 (problem statement, page 1-33 and step 5, page 1-11)
5.	C.	667.5 (page 1-12)
6.	B.	14 (page 1-14)
7.	C.	778.7 (page 1-17)
8.	B.	21 (page 1-18)
9.	A.	1,168.13 (page 1-20)
10.	C.	25 (pages 1-21, and 22)
11.	D.	30 (pages 1-23, and 24)
12.	B.	25 (page 1-25)
13.	D.	Does not apply for snap ties (page 1-26)
14.	A.	121 (page 1-27)
15.	B.	3 (pages 1-28, and 29)
16.	C.	1.5 (page 1-30)

Problem 2

<u>Item</u> <u>Correct Answer</u>

17. B. 405 (page 1-8)

18. B. 92 (pages 1-8, and 9)

19. B. 4.4 (page 1-9)

20. A. 50 (problem statement page 1-38 and step 5, page 1-11)

21. D. 942 (page 1-12)

22. D. 9 (page 1-15)

23. B. 706 (page 1-17)

24. B. 21 (page 1-18)

25. D. 1,648.5 (page 1-20)

26. B. 22 (pages 1-21, and 22)

27. B. 10 (pages 1-23, and 24)

28. C. 10 (page 1-25)

29. C. 9 (page 1-26)

30. C. 124 (page 1-27)

31. C. 4 (pages 1-28, and 29)

32. D. 2.0 (page 1-30)

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APPENDIX A

LIST OF COMMON ACRONYMS

ACCP	Army Correspondence Course Program
AV	Aumotic voice network
cu ft	cubic foot (feet)
cu yd	cubic yard(s)
DSN	defense switching network
EN	engineer
F	Fahrenheit
FM	field manual
ft	foot (feet)
hr	hour
in	inch(s)
IPD	Institute for Professional Development
L	length
lb	pound(s)
lin ft	linear foot (feet)
min	minute(s)
MOS	military occupation specialty
No	number(s)
psf	pound(s) per square foot (feet)
R	rate of placing
REG	regulation

RYE	Retirement Year Ending
SM	soldier's manual
S4S	surfaced on 4 sides
SSN	social security number
STP	soldier's training publication
sq ft	square foot (feet)
sq yd	square yard(s)
TRADOC	Training and Doctrine Command
TG	trainer's guide
UL	uniform load
ULS	uniform load on a stud
ULW	uniform load on a wale
US	United States (of America)
VA	Virginia
W	width
	per

APPENDIX B

RECOMMENDED READING LIST

The following publications provide additional information about the material in this subcourse. You do not need these materials to complete this subcourse.

FM 5-34. *Engineer Field Data*. 14 September 1987.

FM 5-426. *Carpentry*. To be published with in six months.

FM 5-742. *Concrete and Masonry*. 14 March 1985.

STP 5-512B24-SM-TG. *Soldier's Manual, Skill Levels 2/3/4, and Trainer's Guide. MOS 12B, Combat Engineer*. 12 December 1990.

STP 5-51B12-SM-TG. *Carpentry and Masonry Specialist Skill Levels, 1/2 MOS 51B, Soldier's Manual and Trainer's Guide*. August 1987.

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